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The Emergence and Survival of Certain Forage Plants when Seeded in a Saline Soil

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THE EMERGENCE AND SURVIVAL OF CERTAIN FORAGE PLANTS WHEN SEEDED IN A SALINE SOIL

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INTRODUCTION

Salty soils are recognized as an ever increasing problem connected with irrigation agriculture. Millions have been spent by state, federal and private agencies on technical research in an attempt to solve this problem. Other millions have been spent on drainage projects, land leveling, field explorations and soil amendments attempting to alleviate the situation in the field.

Physical conditions such as lack of drainage outlets or the impermeable nature of soils may prevent reclamation. Some areas are physically capable of drainage but the cost would be excessive. This condition necessitates the production of salt tolerant and sometimes water tolerant crops if such lands are to give any returns. Other lands may produce such crops during the reclamation period.

Plants are known to vary in their ability to grow under salty conditions; however, salt tolerance does not insure profitable production. Some highly tolerant plants have little economic value and/or their production on salty soil may be very low.

Some plants are known to be salt tolerant in the mature stage but sensitive in the seedling stage. This study concerns the emergence and survival of certain forage plants when seeded in a saline soil.

The techniques used in approaching this problem have been modified since this study was conducted.

REVIEW OF LITERATURE

The Nature of Salt Injury to Plants

The reduction of plant growth and yield is the most important effect of salt injury to plants. Many workers in this field have noted this reduction of growth and reported it in various ways.

Richards (1947) described a field of crop plants growing on saline soil thus: "Common features are barren spots, stunted growth of the plants with considerable variability in size, and a characteristic deep blue-green coloration."

The factors which bring about this reduction in plant growth will be discussed in a following section.

Nature of Salts

In the past the terms "alkali" and "saline" have been used interchangeably and without definite meaning. The following classification of salty soils is given by Richards (1947) to set up distinct meanings for these two terms:

"Saline soils

"This term will be used in connection with soils for which the conductivity of the saturation extract is more than 4 millimhos/cm. and the exchangeable-sodium-percentage is less than 15. Ordinarily the pH is less than 8.5. These soils correspond to Hilgard's "white alkali" soils and to the "Solonchaks" of the Russians. When adequate drainage is established and the soluble salts are removed by leaching they again become normal soils.

"Owing to the presence of excess salts, and absence of appreciable exchangeable sodium, the colloids in saline soils are highly flocculated. As a consequence, saline soils usually have a favorable structure and are readily permeable to water and air.

"Saline-alkali soils

"This term is applied to soils for which the conductivity of the saturation extract is greater than 4 millimhos/cm. and the exchangeable-sodium-percentage is greater than 15. .... Under conditions of excess salts the pH value is seldom higher than 8.5 and the colloids remain flocculated.

"Nonsaline-alkali soils

"This term is applied to soils for which the exchangeable-sodium-percentage is greater than 15 and the conductivity of the saturation extract is less than 4 millimhos/cm. The pH values generally range between 8.5 and 10. These soils correspond to Hilgard's "black alkali" soils and in some cases to the Solonetz soils as the latter term is used by the Russians and by Kellogg. They frequently occur in semi-arid and arid regions in small irregular areas which are referred to as "slick spots". .... The soil organic matter is highly dispersed and distributed over the soil particles thereby darkening the color. When the soil contains appreciable organic matter its surface may be quite black, hence the term "black alkali".

"Nonsaline-alkali soils occur in western United States for which the exchangeable-sodium-percentage ranges considerably above 15, and yet the pH, especially in the surface soil, may be as low as 6. These soils have been referred to by deSigmond as degraded alkali soils and are classed in the great soil group known as Soloth. They occur only in the absence of lime and the low pH is due to exchangeable hydrogen. The physical properties, however, are dominated by the exchangeable sodium and are typically those of a nonsaline-alkali-soil."

Kearney *et al.* (1936) list the chloride, carbonate, bicarbonate and sulfate salts of sodium, calcium and magnesium and the nitrate salt of sodium as being found in salty soils. The relative proportion and concentration of these salts is the determining factor in the classification of salty soils.

Throughout the remainder of this paper the terms saline, saline-alkali and nonsaline-alkali will be used wherever applicable. The soil used in the experimental work carried on in connection with this thesis falls in the saline class.

Factors Affecting Plant Survival Under Saline Conditions

Physical prevention of water uptake.

The physical effects of salts in preventing water uptake was demonstrated by Wadleigh (1947) in an experiment with beans, corn, alfalfa and cotton plants. These plants were grown in containers 1 foot square and 36 inches deep with the salt concentration increasing from none at the surface to 0.25 per cent at the bottom. Very few bean roots penetrated beyond the layer containing 0.1 per cent NaCl. A few corn roots penetrated the layer containing 0.2 per cent NaCl while a few alfalfa roots penetrated the layer containing 0.25 per cent NaCl. Cotton roots were abundant throughout the soil column. The different plants varied in their ability to withdraw water from the soil but water was removed to such a degree that final osmotic pressure of all the layers in the soil column were nearly uniform. Critical osmotic pressures of the soil solution for beans were 7 to 8 atmospheres and cotton 16 to 17 atmospheres.

Magistad and Reitemeier (1943) found that soils were barren above 40 atmospheres concentration while normal fertile soils had a soil solution concentration at wilting percentage of 1.3 to 1.8 atmospheres, conductance values ($K \times 10^5$) of 200 to 350; 2,000 to 4,000 p.p.m. and 30 to 50 m.e. per liter of salts. These authors further state that, "It has been customary to correlate plant behavior with the salt content of a soil expressed in terms of percentage or parts per million on a dry soil basis. It is more logical to give salt concentrations on the basis of soil solution rather than of soil."

Magistad (1943) reported that there was no evidence that a given concentration of a solution may be regarded as critical but rather that there tended to be a linear relationship between growth reduction and increase in salt concentration of the solution as expressed in atmospheres.

The relationship between the osmotic pressure of soil solution and water uptake by plants is explained by Thorne and Peterson (1947) in the following: "Since the ease of water absorption by plants is probably the function of the diffence between the osmotic pressure of the soil solution and the physical tension on it, any drastic fluctuation in osmotic pressure in the soil solution would greatly influence water availability."

Wadleigh and Gauch (1944) demonstrated that different salts affect certain plants differently at the same osmotic pressure. In their study guayule proved very sensitive to magnesium, the plants being killed by the lowest concentration (1.5 atmospheres) of magnesium chloride used. On the other hand this plant was very tolerant of calcium chloride making satisfactory growth in the presence of 5 atmospheres of added calcium chloride. The sensitivity of this plant to sodium sulphate and sodium chloride lies between its sensitivity to magnesium and calcium.

Chemical disturbance of nutrition and metabolism.

The nitrogen and carbohydrate fractions of plants have received major attention of researchers studying the effect of salts on plant metabolism. Wadleigh and Ayers (1945) found that increasing salt concentration tended to increase the percentage of nitrate nitrogen in bean plants, while sugars in the stems and starch in the leaves decreased as salt increased.

In contrast to the above report, Gauch and Wadleigh (1945) found that increasing amounts of sodium chloride, calcium chloride and sodium sulphate tended to decrease progressively the concentration of total nitrogen in the plant tissues, but this effect may be attributed to the season of the year. They also found that phosphate concentrations in the plant were affected very little by the addition of salt to the base nutrient solution used. Potassium concentration in the leaves decreased when calcium chloride was the added salt, while the calcium concentration increased. The addition of sodium chloride had very little effect upon the calcium-potassium relationship while the addition of sodium sulphate lowered the calcium content and increased the potassium content of the leaves.

Salt tolerance was considered a phenomenon of adaptation by Breazeale (1926) in the following:

> "The limit of endurance of a plant for alkali salts seems to be determined by the amount of alkali that is required to kill the enzymes of the roots that are concerned with growth. There seems to be a definite order of toxicity of alkali salts and the position of each salt in the order of toxicity depends upon the time that the plant has been in contact with salt during its period of adaptation. Calcium, even in minute quantities, increases enormously the tolerance of wheat seedlings for NaCl and other salts. Plants can utilize calcium at one period and this may be effective in overcoming alkali at a later period. Plants may be inoculated or immunized against alkali, with calcium, just as readily as animals can be inoculated or vaccinated against certain diseases. Alkali tolerance in plants and immunity to disease in animals are closely allied in that both are phenomena of adaptation."

Indirect alteration of soil structure, permeability and aeration.

"Salinity and alkali may exert a secondary effect on plant growth as a result of adverse modifications of the soil itself. Thus, if the exchange complex of the soil contains appreciable amounts of sodium, the soil may become dispersed and puddled, thereby causing poor aeration and low water availability. This is especially the case in heavy soil." Richards (1947)

Thorne and Peterson (1947) state that a high water table and fine texture with a dense impermeable clay subsoil often complicate the effects of saline conditions on soil properties. A good soil structure may be maintained by an excessive quantity of salt but with leaching the sodium becomes involved with the clay. This results in an increase of pH, swelling of the clay and deflocculation which impedes drainage and aeration.

Factors Affecting Plant Survival under Alkali Conditions

Caustic alkalinity and carbonate ion toxicity.

Magistad and Christiansen (1944) report that few plants will grow when the soluble carbonates present exceed 20 p.p.m. as this salt seems to have a corrosive action on the plants. Thorne and Peterson (1947) say that when the pH of the soil exceeds 9 some plant roots and organic matter are dissolved.

"In addition to unfavorable physical condition and lack of calcium, alkali soils usually have high pH values, with attendant unavailability of several essential elements such as iron, manganese, phosphates and at times nitrates.

"In alkali soils of low salt content some sodium carbonate is present. The alkali carbonates are very toxic and even corrosive to plant parts. Probably only in the most extreme cases is there any appreciable amount of free sodium carbonate." Magistad (1945)

Exchangeable sodium.

"Some of the available data show that plant nutrition is noticeably affected at an exchangeable-sodium-percentage of 25 to 40, while at a percentage of 60 to 70 growth may be entirely inhibited, owing to malnutrition. Calcium nutrition is strongly suspected to be one of the causes of malnutrition in such cases." Richards (1947)

Plant Ratings for Relative Salt Tolerance

Forage crops are likely to give the most satisfactory results on saline soils. Among these crops hay and pasture plants, which are grown principally for their stems and leaves, are to be preferred to such plants as kafir, milo, or proso in which seed production is an important feature. Kearney et al. (1936)

Leguminous forage plants are generally sensitive to salinity and very few species grow naturally in salty soils. They are sensitive to sodium carbonate and their culture should not be attempted in so-called "black alkali" soil. Under medium salts (0.4 - 0.6%) alfalfa, sweet clover, field peas, horsebeans, and some vetches may be grown. Kearney _et al._ (1936) say that strawberry clover is fair at 2.0% but moist soil is necessary, while Larson (1938) says that this plant has its greatest value on wet lands of low salinity.

"Not only is there a difference in the salt tolerance of plants according to variety, but there are also significant differences in strains of some varieties. This point is being further investigated but such differences have already been found for cotton and strawberry clover. This indicates the possibility of plant breeding for salt tolerance." Richards (1947)

"The accompanying list is based on the Magistad-Christiansen (1944) list with some additions and modifications. It is presented here realising that it is far from complete." Richards (1947)

Table 1. Classification of forage crops according to salt tolerance.

"In each group the plants first named are considered to be more tolerant and the last named more sensitive to salinity." Richards (1947)

Good Salt Tolerance	Moderate Salt Tolerance	Poor Salt Tolerance
I	II	III
Alkali sacaton	White sweet clover	White (Dutch) clover
Salt grass	Yellow sweet clover	Meadow foxtail
Nuttall alkali grass	Perennial rye grass	Alsike clover
Bermuda grass	Mountain brome	Red clover
Rhodes grass	Barley (hay)	Ladino clover
Rescue grass	Birdsfoot trefoil	Burnet
Canada wild rye	Strawberry clover	
Beardless wild rye	Dallis grass	
Western wheat grass	Sudan grass	
	Hubam clover	
	Alfalfa (Calif. Common)	
	Tall fescue	
	Rye (hay)	
	Wheat (hay)	
	Oats (hay)	
	Orchard grass	
	Blue grama	
	Meadow fescue	
	Reed canary	
	Big trefoil	
	Smooth brome	
	Tall meadow oat grass	
	Cicer milk vetch	
	Sour clover	
	Sickle milk vetch	

Soil Management to Improve the Production of Forage Plants on Salty Soil

Kearney *et al.* (1936) propose the following cultural and irrigation practices for reclaiming white alkali (saline) soils:

1. Land should be leveled very carefully to allow uniform irrigation.

2. The best possible condition of tilth for a seedbed should be established.

3. After seeding, keep the surface moist by frequent light irrigations. Subsequently irrigation water should be applied as frequently as possible without injuring the growing crop. These recommendations involve basin and check irrigation, not furrow irrigation as the letter should never be practiced if the other methods are feasible.

The work of Greaves (1927) indicated that the addition of soil extract or manure to leached salty soils was very effective in restoring ammonification and nitrification. The addition of manure should be included in the soil management practices used on salty soil.

The germination and seedling stages are the most critical in the life of the plant with regards to salt tolerance. This is substantiated by the work of Harris (1915) and Uhvits (1946). The latter author reported that NaCl solution of 12 to 16 atmospheres practically inhibited the germination of alfalfa seed.

Many workers have pointed out the tolerance of mature alfalfa plants and some have reported on the sensitivity of the same plant in the seedling stage. This relationship demands special care in seedbed preparation and management to reduce the salt content of the surface soil during the early growth stages.

MATERIALS AND METHODS

Field Planting

On May 11, 1940 a planting involving a number of pasture species was made on saline soil on the A. J. Favero farm located 7 miles west of Ogden, Weber County, Utah. This planting was made in cooperation with the Weber County Agricultural Agent and the farm owner.

A composite soil sample (0 - 8") collected on the experimental area had a pH of 8.1 as determined by the Beckman pH meter. The textural class of the sample was a silt loam with fifteen per cent fine gravel and sand, sixty-two per cent silt and twenty-three per cent two micron clay.

Table 2. Salt content of the soil and water samples from the field plots.

(p.p.m.)

Depth	Number of Samples	Dates Sampled 6/5/40	10/5/40	4/26/41	8/5/41
0 - 7"	20	1,942*	2,680	1,614	
8 - 24"	20	3,873	3,622	3,588	
0 - 6"	11				2,238
7 - 18"	11				3,408
Soil Water	2	35,980			
	1			34,580	
Irrigation Water	1	515			

* Figures are averages of the number of samples indicated.

The planting consisted of 36 species arranged in four randomized blocks and each plot was 4' X 20'. The land was rough, having been broken from salt grass sod the spring before and summer fallowed. This necessitated broadcasting the seed instead of drilling. A heavy seeding of two ounces per plot (68 lbs. per acre) was sown due to the unfavorable seedbed.

Immediately after planting the plots were lightly raked to cover the seed. Irrigation followed soon after. Plant growth notes and soil samples (for salt determinations) were taken four times (two in 1940 and two in 1941).

These plots were irrigated with runoff from land above the experimental area. The farm owner applied water only during his regular turn; consequently these plots were alternately wet and dry. The area was not sufficiently level to permit uniform water application.

Greenhouse Studies

During October 1940 a greenhouse study was initiated to determine the effect of salts in soil on the emergence and survival of 12 forage species, some of which had proved fair in the field planting and others about which we desired information.

Soils with varying salt concentrations were secured from the experimental field plots by the aid of the Wheatstone electric bridge. The six concentrations (1,000; 4,000; 8,000; 12,000; 16,000 and 20,000 p.p.m.) were found within a small area. The soil was removed to shovel depth and placed in individual containers. Another soil containing 40,000 p.p.m. salt was secured at a later date from the same field.

The lowest salt concentration, around 1,000 p.p.m., found in the field came from the low places where the water stood after each rain or irrigation. These depressions generally supported very little plant growth, but the soil therein contained considerable organic matter (Table 3). Immediately surrounding these low spots, at a slightly higher level, was a ring of desert salt grass and above this ring on the tops of the rises was very little plant growth. Salt concentrations increased from the bottom of the depressions to the top of each rise. The highest salt concentration, 40,000 p.p.m., was found on a rise which had a one-half inch crust of white salt at the surface.

Approximately two hundred pounds of soil were secured for each salt concentration. The soil was air dried, ground and screened through a sixteen mesh screen before placement in flats. Samples were taken from each concentration for analysis.

Table 3. Analysis of the samples used in the greenhouse studies.

Sample No.	Desired * Salt Content p.p.m.	Actual Salt Content - Bridge p.p.m.	Water Soluble Salts p.p.m.	Org. Mat. Schollenberger %
1.	1,000	1,051	1,370	1.06
2.	4,000	3,286	2,980	0.62
3.	8,000	6,065	5,860	0.69
4.	12,000	10,899	10,180	0.65
5.	16,000	13,900	12,500	0.65
6.	20,000	21,995	18,600	0.65
7.**	40,000	-	-	-
8.***	Check	-	-	-

Sample No.	Equivalents Per Million						
	Na^+	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}
1.	27.0	1.8	0.3	1.9	14.9	6.1	6.2
2.	52.2	1.1	0.8	5.7	19.1	23.5	5.8
3.	87.1	0.9	1.8	6.7	12.6	54.5	16.0
4.	140.3	1.2	2.0	2.8	13.8	90.4	36.5
5.	184.7	1.8	1.1	19.6	9.0	118.1	40.9
6.	213.3	1.7	2.3	10.4	11.9	161.1	33.9
7.**	-	-	-	-	-	-	-
8.***	-	-	-	-	-	-	-

* These were the desired salt concentrations and those sought for while sampling in the field.

** This sample was secured later than the first six and was not analyzed beyond the bridge test.

*** Check soil - regular greenhouse potting soil.

The sodium ions were figured by difference after the other ions had been determined quantitatively. The sum of the cations equals the sum of the anions. Sodium chloride was the most prevalent salt in these samples. Potassium was not considered in the tests or calculations.

Galvanized metal flats (14" x 24" x 4") were used for the greenhouse test. There were four flats of each of the eight concentrations. Each flat held about forty pounds of soil.

As a precaution against damping-off, one hundred ml. of concentrated acetic acid was thoroughly mixed with the soil in each flat, the flats covered and allowed to stand overnight.

Preliminary trials showed that eight pounds of water would bring the forty pounds of soil in each flat to optimum moisture (20 per cent moisture dry-weight basis). A baffle plate, consisting of a rectangular tin sheet (12" x 18"), was used to prevent soil washing during the irrigating. This plate was placed on top of the dry leveled soil and the water poured thereon.

Fourteen rows one and three-fourths inches apart were made across the width of each flat. One hundred seeds were sown in each row and covered with about one-half inch of soil. The two end rows of each flat were planted to white sweet clover to serve as guard rows.

Water was added on a weight basis every other day and the soil in each flat brought back to its original moisture content.

EXPERIMENTAL RESULTS

Field Planting

Estimates were made as to the per cent stand and condition of the plants on June 26, 1940; October 5, 1940; March 20, 1941 and August 5, 1941.

The forage species and vaieties were classified into four groups with regard to survival on saline soil. (See Table 4)

Table 4. Classification of the species and varieties grown in the field with regards to their survival on a saline soil.

Good - 40 to 70% stand.	
Perennial rye grass	*Lolium perenne*, L.
Meadow fescue	*Festuca elatior*, L.
Alfalfa (Turkestan 86696)	*Medicago sativa*, L.
Reed canary grass	*Phalaris arundinacea*, L.
Slender wheat grass	*Agropyron pauciflorum*, (Schwein) Hitchc.
Smooth brome grass	*Bromus inermis*, Leyss
Western wheat grass	*Agropyron smithii*, Rybd.
White sweet clover	*Melilotus alba*, Desr.
Moderate - 20 to 40% stand.	
Orchard grass	*Dactylis glomerata*, L.
Alfalfa (Pioneer)	*Medicago sativa*, L.
Redtop	*Agrostis alba*, L.
Strawberry clover	*Trifolium fragiferum*, L.
Alfalfa (Turkestan 19304)	*Medicago sativa*, L.
White (Dutch) clover	*Trifolium repens*, L.
Alfalfa (Grimm)	*Medicago sativa*, L.
Fair - 10 to 20% stand.	
Yellow sweet clover	*Melilotus officinalis*, (L.) Lam.
Crested wheat grass	*Agropyron cristatum*, L. (Gaertn.)
Mammoth red clover	*Trifolium medium*, Huds.
Alsike clover	*Trifolium hybridum*, L.
Timothy	*Phleum pratense*, L.
Graham's mammoth red clover	*Trifolium medium*, Huds.
Alfalfa (Turkestan composite)	*Medicago sativa*, L.
English wild white clover	*Trifolium repens sylvestre*, Alef. Landw.
Poor - 0 to 10% stand.	
Blue grama grass	*Bouteloua gracilis*, (H.B.K.) Lag.
Buffalo grass	*Buchloe dactyloides*, (Nutt.) Engelm.
Tall meadow oat grass	*Arrhenatherium elatius*, (L.) Beauv.
Alfalfa (yellow flowered)	*Medicago falcata*, L.
Louisiana white clover	*Trifolium repens*, L.
Red clover	*Trifolium pratense*, L.
Ladino clover	*Trifolium repens B giganteum*, Lagr.-Foss
Astragalus	*Astragalus rusbyi*, Greene
Kentucky blue grass	*Poa pratensis*, L.
Canada Blue grass	*Poa compressa*, L.
Little blue stem	*Andropogon scoparius*, Michx.
Sheep fescue	*Festuca ovina*, L.
Creeping bent grass	*Agrostis stolonifera*, L.

Greenhouse Studies

High percentage of emergence was secured in the check soil and the 1,000 p.p.m. concentration with lower emergence in the 4,000 p.p.m. and still lower in the 8,000 p.p.m. concentrations. Salt concentrations higher than the latter completely inhibited emergence.

For data of this nature the chi-square (X^2) test is appropriate. The highly significant chi-square figures at the bottom of tables 5 and 6 indicate that the data is heterogeneous, the observed do not fit the calculated and variables (species and concentrations) are associated and/or interacting. The two asterisks following the chi-square (X^2) figures denote signifcance beyond the 1% level.

Table 5 shows the chi-square analysis of the emergence data. The small "x" represents the total number of seedlings emerging in the four replications and "m" represents the estimated number based on the emergence totals.

Table 6 shows the chi-square analysis of the data on the number of plants surviving after a period of 28 days. A considerable number of plants failed to survive through this period with the greatest losses in the higher concentrations. All the emerging plants in a number of species died in the 8,000 p.p.m. concentration. This necessitated omitting the data on this concentration from the chi-square analysis for surviving plants.

Table 5. Chi-square analysis of emergence data.

Salt p.p.m.		Alsike Clover	Pioneer Alfalfa	Red Clover	Straw-berry Clover	White (Dutch) Clover	White Sweet Clover	Meadow Fescue	Perenni-al Rye Grass	Redtop	Reed Canary Grass	Smooth Brome Grass	Timothy	Total
Check soil	x	195	363	301	194	257	104	373	384	261	88	349	250	3119
	m	156.6	382.0	330.8	211.2	231.0	121.8	404.1	406.7	237.0	72.1	337.6	227.7	
	x-m	38.4	-19.0	-29.8	-17.2	26.	-17.8	-31.1	-22.7	24.0	15.9	11.4	22.3	
1,000	x	141	350	327	199	252	100	364	385	215	64	330	237	2964
	m	148.8	363.0	314.4	200.7	219.6	115.8	384.0	386.5	225.2	68.5	320.8	216.4	
	x-m	-7.8	-13.0	12.6	-1.7	32.4	-15.8	-20.0	-1.5	-10.2	-4.5	9.2	20.6	
4,000	x	80	256	231	162	108	86	320	282	157	41	218	120	2061
	m	103.5	252.5	218.6	139.6	152.6	80.5	267.0	268.8	156.6	47.6	223.0	150.4	
	x-m	-23.5	3.5	12.4	22.4	-44.6	5.5	53.0	13.2	0.4	-6.6	-5.6	-30.4	
8,000	x	3	53	26	10	1	36	24	37	1	0	6	2	199
	m	9.9	24.4	21.1	13.4	14.7	7.8	25.7	25.9	15.1	4.6	21.5	14.5	
	x-m	-6.9	28.6	4.9	-3.4	-13.7	28.2	-1.7	11.1	-14.1	-4.6	-15.5	-12.5	
Total		419	1022	835	565	618	326	1081	1088	634	193	903	609	8343

$$X^2 = S \frac{(x-m)^2}{m} = 286.4 \;**$$

$$d.f. = (R-1)\ (C-1) = 33$$

x = Total number of seedlings emerging out of a possible 400 distributed 100 to a replication.

m = Calculated emergence figure on the basis of column total times row total divided by grand total.

x - m = Difference

** Indicate that the chi-square (X^2) figure is highly significant.

Table 6. Chi-square analysis of surviving plants after 28 days.

Salt p.p.m.		Alsike Clover	Pioneer Alfalfa	Red Clover	Straw-berry Clover	White (Dutch) Clover	White Sweet Clover	Meadow Fescue	Perenni-al Rye Grass	Redtop	Reed Canary Grass	Smooth Brome Grass	Timothy	Total
Check soil	x	86	235	267	188	188	89	369	379	256	82	344	244	2727
	m	67.1	262.5	262.2	204.5	144.2	93.7	401.6	405.5	239.9	69.1	351.1	225.2	
	x-m	18.9	-27.5	4.8	-16.5	43.8	-4.7	-32.6	-26.5	16.1	12.9	-7.1	18.8	
1,000	x	70	305	278	185	157	96	330	365	206	55	326	214	2587
	m	63.7	249.1	248.7	194.0	136.8	88.9	380.9	384.7	227.6	65.5	333.1	213.6	
	x-m	6.3	55.9	29.3	-9.0	20.2	7.1	-50.9	-19.7	-21.6	-10.5	-7.1	0.4	
4,000	x	13	121	115	142	18	51	312	277	142	37	214	109	1551
	m	38.1	149.3	149.1	116.4	82.0	53.3	228.4	230.7	136.5	39.3	199.7	128.1	
	x-m	-25.1	-28.3	-34.1	25.6	-64.0	-2.3	83.6	46.3	5.5	-2.3	14.3	-19.1	
Total		169	661	660	515	363	236	1011	1021	604	174	884	567	6865
8,000 *		0	21	5	3	0	3	21	29	0	0	2	2	86

$$\chi^2 = \frac{(x-m)^2}{m} = 194.62 \; **$$

d.f. = (R-1) (C-1) = 22

* There were too many zeros in this row to permit its use in calculations.

The data in tables 5 and 6 show that wherever the observed value ("x") is large as compared with the calculated ("m") value especially in the higher concentrations it is indicative of salt tolerance. In other words those species which have high plus values of x-m do relatively better than other species at the higher concentrations so far as emergence and survival as seedlings are concerned.

In the emergence data (table 5) meadow fescue has the high plus value of 53.0 for x-m at 4,000 p.p.m. concentration but drops to -1.7 in the 8,000 p.p.m. concentration. Strawberry clover had a similar drop from 22.4 to -3.4. This indicates that these species emerge relatively better at 4,000 p.p.m. than at 8,000 p.p.m. concentration. On the other hand pioneer alfalfa and white sweet clover increased from 3.5 to 28.6 and 5.5 and 28.2 respectively from the 4,000 to the 8,000 p.p.m. concentration. This does not mean that pioneer alfalfa and white sweet clover emerge better at 8,000 p.p.m. than at 4,000 p.p.m. concentration but their relative emergence was better at 8,000 than that of the other species used in the test.

The grasses had plus values for x-m in the survival data (table 6) at the 4,000 p.p.m. concentration with the exceptions of reed canary grass and timothy. The legumes had minus values of x-m with the exception of strawberry clover. This indicates that the legumes used in this test were perhaps less tolerant to salt injury during the seedling stage than were the grasses used.

Pioneer alfalfa, meadow fescue and perennial rye grass were the only species with appreciable numbers surviving after growing 28 days at 8,000 p.p.m. concentration.

There was little over-all difference in the emergence between the check soil and 1,000 p.p.m. concentration; however, with regards to survival the 1,000 p.p.m. concentration seemed to have some stimulating effect especially upon the legumes. The 4,000 p.p.m. concentration considerably reduced the emergence and survival when compared with the 1,000 p.p.m. concentration, while the 8,000 p.p.m. concentration greatly reduced the results over those secured in the 4,000 p.p.m. concentration. No seedlings emerged in the 12,000 p.p.m. or higher concentrations.

The low emergence of reed canary grass in all concentrations might be attributed to hard, impermeable seed. This condition is quite common with this species.

An increase in the seeding rate on salty soils might overcome the reduction in stand due to seedling mortality and result in fair stands of mature plants.

SUMMARY

Thirty-six forage species and varieties were planted in May 1940 on a saline soil in Weber County, Utah. The salt content of the experimental area was approximately 2,000 p.p.m. in the 0-7" layer and 3,600 p.p.m. in the 8-24" layer. Ground water contained approximately 36,000 p.p.m. salt and the irrigation water 500 p.p.m. salt.

Plant growth notes of the stand secured and of the general appearance of the plants were taken twice in 1940 and twice in 1941. On the basis of these findings the various species and varieties were classified as to salt tolerance.

Perennial rye grass, meadow fescue, alfalfa (Turkestan 86696), reed canary grass, slender wheat grass, smooth brome grass, western wheat grass and white sweet clover proved the most tolerant of the saline conditions found in the field. These species produced an estimated stand of between 40 and 70%.

After the field experiments were partially completed, six legumes and six grasses were chosen for further study in the greenhouse. The choice of these species was partially based on field results. This further study involved the planting of these species in soils of varying salt concentrations and making counts as to the number emerging and surviving after 28 days.

The concentrations chosen were 1,000; 4,000; 8,000; 12,000; 16,000; 20,000 and 40,000 p.p.m. and samples of these were secured from the field experimental area. Regular greenhouse potting soil was used as a check.

The 1,000 p.p.m. concentration seemed to stimulate seedling emergence of some species over that secured in the check soil. Emergence decreased progressively in the 4,000 and 8,000 p.p.m. concentrations with no emergence in the 12,000 p.p.m. or higher concentrations.

Many seedlings failed to survive a 28 day growing period in the greenhouse. Generally speaking, grass seedlings seemed to be more tolerant to salt than legume seedlings.

Outstanding species with regard to survival in the seedling stage were meadow fescue, perennial rye grass and strawberry clover but the relative listing changed as the concentration increased or the growth period lengthened.

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